

# INCOHERENT VERSUS COHERENT MATCHED MODE PROCESSING FOR SHALLOW WATER SOURCE LOCALISATION USING A SINGLE HYDROPHONE

B. Nicolas<sup>1</sup>, G. Le Touzé<sup>1</sup>, C. Soares<sup>2</sup>, S. Jesus<sup>2</sup>, J.I. Mars<sup>1</sup>

(1) GIPSA-LAB, Dep Image Signal, 961, Rue de la Houille Blanche, BP 46, 38402 St Martin d'Heres Cedex, France  
barbara.nicolas@gipsa-lab.inpg.fr

(2) SIPLAB, FCT-Universidade do Algarve, Campus de Gambelas, 8005-139 Faro, Portugal

**Abstract** - The aim of this paper is to propose a method of source localization using a single hydrophone in shallow water. To perform this localization, modes are first filtered in the time-frequency plane and then used in two different Matched Mode Processors: Incoherent and Coherent broadband processors. Results on simulated data are presented.

**Keywords** - source localization, shallow water, modal filtering, Matched Mode Processing.

## I. INTRODUCTION

Source localisation using a single hydrophone is a challenging task. A few methods have been proposed [1,2] but either they are sensitive to the environment knowledge or not adapted to Ultra Low Frequency sources (1-100 Hz) in shallow water environment. In this paper we propose two Matched Mode Processing methods based on modal filtering in the time-frequency plane to localize an Ultra Low Frequency source in depth and range using a single hydrophone.

## II. MODAL FILTERING AND MATCHED MODE PROCESSING

### A) Modal Propagation:

Considering an Ultra Low Frequency source (1-100 Hz) in a shallow water environment allows the use of normal mode theory to model the propagation. In this case, for a broadband source  $S$  located at  $(R_s, Z_s)$  in a classical Pekeris waveguide (made of two isovelocity layers), the received acoustic field on the hydrophone  $M(0, Z_h)$  is expressed, in the frequency domain, by:

$$Y_{real}(R_s, Z_s, \nu, Z_h) = \sum_{m=1}^M X_{real}(R_s, Z_s, \nu, Z_h, m)$$

where  $m$  is the mode  $m$  recorded at frequency  $\nu$  on the hydrophone.

### B) Modal Filtering:

The first step of the method consists in filtering the modes  $X_{real}$  that will be used in the Matched Mode Processing. This step is done using a time-frequency representation (t-f) adapted to guided propagation in underwater acoustics [3]. We must note that the t-f transform can be used to filter modes only if the length time of the source is short compared to the differences between mode time arrivals.

### C) Matched Mode Processing:

Once modes have been filtered, they are used in the processors. We adapt works from Matched Field Processing to Matched Mode Processing using a single hydrophone: a signal recorded on a hydrophone is replaced by a mode.

**Incoherent Matched Mode Processing:** We first build the data vectors and the replica vectors (which are column vectors), at each frequency, in the following way:

$$X_{real}(R_s, Z_s, \nu) = [X_{real}(R_s, Z_s, \nu, Z_h, m_1) \dots X_{real}(R_s, Z_s, \nu, Z_h, m_M)]^T$$

$$P_{simu}(r, z, \nu) = [P_{simu}(r, z, \nu, Z_h, m_1) \dots P_{simu}(r, z, \nu, Z_h, m_M)]^T$$

where  $r$  and  $z$  denotes the possible locations of the source and  $T$  is the transpose operator. Then, the classical Bartlett processor is built:

$$B_{Incoherent}(r, z, \nu) = \frac{P_{simu}^H(r, z, \nu) X_{real}(R_s, Z_s, \nu) X_{real}^H(R_s, Z_s, \nu) P_{simu}(r, z, \nu)}{\|P_{simu}(r, z, \nu)\|^2 \|X_{real}(R_s, Z_s, \nu)\|^2}$$

where  $H$  is the conjugate transpose operator. Localization is then performed by maximizing the following function :

$$B_{Incoherent}(r, z, \nu) = \frac{P_{simu}^H(r, z, \nu) X_{real}(R_s, Z_s, \nu) X_{real}^H(R_s, Z_s, \nu) P_{simu}(r, z, \nu)}{\|P_{simu}(r, z, \nu)\|^2 \|X_{real}(R_s, Z_s, \nu)\|^2}$$

**Coherent Matched Mode Processing:** The aim of this processor is to process frequencies coherently [4]. To do so, as proposed in [5], a normalised super-vector is built for the real data and for each simulation. As an example, for the real data, the column super-vector (SV) is:

$$X_{S_{real}}(R_s, Z_s) = [X_{real}(R_s, Z_s, \nu_1) \dots X_{real}(R_s, Z_s, \nu_F)]^T$$

Then to avoid problems due to the source phase, the data are scaled at each frequency so that they have zero phase on the most energetic mode (this scaling will be indicated using the subscript PC for Phase Compensated) and unit length. Then, the correlator is built:

$$B_{Coherent}(r, z, \nu) = \frac{P_{simu}^H(r, z, \nu) X_{S_{real}}(R_s, Z_s, \nu) X_{S_{real}}^H(R_s, Z_s, \nu) P_{simu}(r, z, \nu)}{\|P_{simu}(r, z, \nu)\|^2 \|X_{S_{real}}(R_s, Z_s, \nu)\|^2}$$

The source location is finally estimated by maximising the previous correlator.

## III. APPLICATION ON SIMULATED DATA

We simulate a Pekeris waveguide of 130 m depth with a water velocity of 1520 m/s and a bottom velocity of 1875 m/s. The source is an unknown impulsive source (frequency band: 1-70 Hz) located at  $Z_s=40$  m and  $R_s=5000$  m. We use the 7 first modes to perform the localization.

To estimate the processor performances, we define two criteria : the width of the main lobe of the ambiguity surface (at 75%) and the ratio between the main ML and secondary SL lobes (defined by  $10 \log_{10} (ML/SL)$  and equal to infinity in the best case and to 0 in the worst). Ambiguity planes for Incoherent and Coherent processors are presented on figure 1 and criteria are summarised in Table 1. We can see that in both cases the localization is achieved but that localization using Coherent MMP is more accurate (smaller width, higher ratio ML-SL).

Method	Ratio ML-SL	Vertical width	Horizontal width
Incoherent MMP	1.42 dB	16 m	140 m
Coherent MMP	1.86 dB	15 m	120m

Table 1. Ratio ML-SL and lobe width for the Incoherent and Coherent MMP

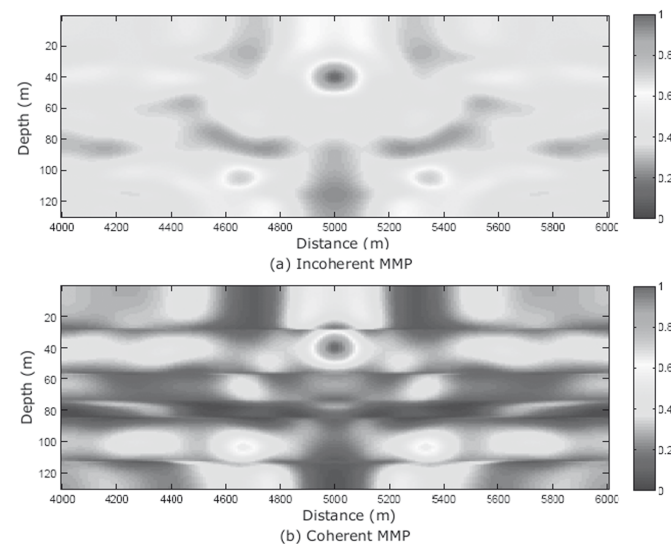


Fig. 1. Ambiguity planes for source localisation using Incoherent (a) and coherent (b) Matched Mode Processing

#### IV. CONCLUSIONS

We propose two Matched Mode Processors to localise sources in shallow water environments using a single hydrophone. We show that the Coherent Processor allows a more accurate localisation as well as a reduction of the side lobes. This processor has now to be studied in detail and applied to real data to prove its efficiency.

#### REFERENCES

[1] L. N. Frazer and P. I. Pecholcs. Single hydrophone localization, *J. Acoust. Soc. Am.*, 88, pp. 995-1002, 1990.

[2] W. A. Kuperman, G. L. D'Spain and K. D. Heaney. Logn range source localization from single hydrophone spectrograms, *J. Acoust. Soc. Am.*, vol. 109, pp. 1935-1943, 2001.

[3] G. Le Touzé, B. Nicolas, J. Mars and J.-L. Lacoume. Matched time-frequency representations and filters for guided waves. *IEEE Trans. Signal Processing*, 2009, to be published.

[4] A. Tolstoy. *Matched Field Processing for Underwater Acoustics*. World Scientific, 1993.

[5] Z.H. Michalopoulou and M. B. Porter. Matched-field processing for broad-band source localization. *IEEE J. Oceanic Eng.*, vol. 21(4), pp. 384-391, 1996

## NORMALITY TESTS ANALYSIS OF RADIOMETRIC SIGNALS FOR RADIO FREQUENCY INTERFERENCE DETECTION

**J. M. Tarongi, A. Camps**

**Centro Mediterráneo de Investigaciones Marinas y Ambientales (CMIMA)**

Radio-frequency interference (RFI) present in microwave radiometry measurements leads to erroneous radiometric results. RFI sources include spurious signals and harmonics from lower frequency bands, spread-spectrum signals overlapping the "protected" band of operation, or out-of-band emissions not properly rejected by the pre-detection filters due to its finite rejection. RFI sources' density increases in populated areas, as shown in [1].

RFI addition to the radiometric signal modifies the detected power and the estimated antenna temperature from which the geophysical parameters will be retrieved. In recent years, techniques to detect the presence of RFI in radiometric measurements have been developed. They include time- and/or frequency domain analyses [2], or statistical analysis of the received signal which, in the absence of RFI, must be a zero-mean Gaussian process. The statistical analysis of the received signal includes the calculation of the Kurtosis parameter to compare it with the Kurtosis of a Gaussian signal [3], and the Shapiro-Wilk normality test to the received signal [4]. Nevertheless, statistical analysis of the received signal could be more extensive, as in statistical literature several normality tests have been developed.

The motivation of this paper is the study of a set of normality tests applied to the received signal as the radiometric signal presents a Gaussian nature; observing the best normality test for different RFI components. A description of the normality tests and the RFI detection results for different kinds of RFI are presented.

#### REFERENCE

[1] Ellingson, S. W.; and Johnson, J. T.; "A Polarimetric Survey of Radio-Frequency Interference in C- and X-Bands in the Continental United States Using WindSat Radiometry", *IEEE Transactions on Geoscience and Remote Sensing* Mar. 2006, Vol. 44(3), 540-548.

[2] Guner, B.; Johnson, J. T.; and Niamsawaun, N.; "Time and frequency blanking for radio frequency interference mitigation in microwave radiometry", *IEEE Transactions on Geoscience and Remote Sensing* Nov. 2007, Vol. 45(11), 3672-3679.

[3] Ruf, C. S.; Gross, S. M.; and Misra, S.; "RFI detection and mitigation for microwave radiometry with an agile digital detector", *IEEE Transactions on Geoscience and Remote Sensing* Mar. 2006, Vol. 44(3), 694-706

[4] Guner, B.; Frankford, M. T. and Johnson, J. T.; "A study of the Shapiro-Wilk test for the detection of Pulsed Sinusoidal Radio Frequency Interference", *IEEE Transactions on Geoscience and Remote Sensing* Jun. 2009, Vol. 47(6), 1745-1751.

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